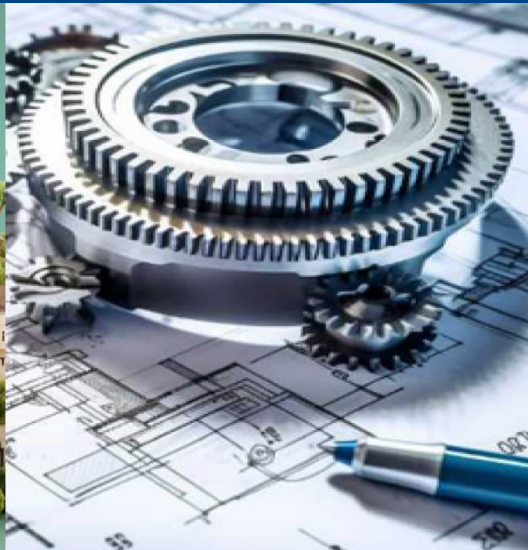
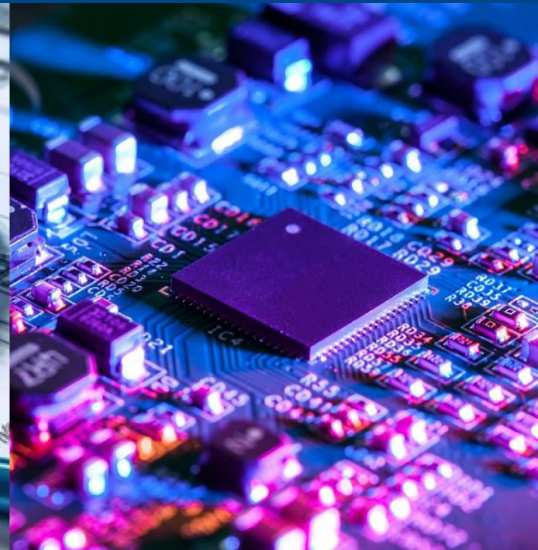
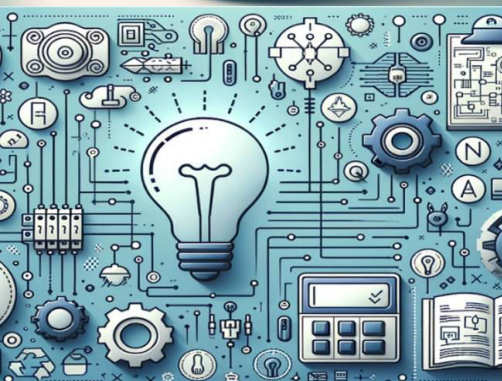




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“Experimental Investigation of Phase Change Material Integrated Concrete Thermal Regulation and Strength Optimization in Hot Climate Condition”

Srushti Sul¹, Vaishnavi Awatade¹, Prajakta Raut¹, Tanisha Landage¹, Prof. Sonali Patil²

UG Student, Dept. of CE, SVERI's College of Engineering, Pandharpur, Solapur, India¹

Assistant Professor, Dept. of CE, SVERI's College of Engineering, Pandharpur, Solapur, India²

ABSTRACT: This paper describes a planned experimental study of concrete containing phase change material (PCM), aimed at improving heat regulation in hot-climate buildings without an unacceptable loss of strength. Paraffin wax serves as the heat-storing material, and expanded perlite holds it in place to prevent leakage. Four mixes with 0%, 5%, 10% and 15% PCM (M0, M5, M10 and M15) will be cast and compared against conventional concrete. Heating and cooling exposure will be used to record peak temperature, temperature rise, time to peak and temperature variation, while cube tests at 7 and 28 days will give compressive strength. Earlier work on mortar and panels indicates that PCM improves heat storage but lowers strength; the study therefore seeks the PCM dosage that offers the best compromise between the two. Results will be presented in a subsequent report.

KEYWORDS: Phase change material, paraffin wax, expanded perlite, concrete, thermal regulation, compressive strength, hot climate.

I. INTRODUCTION

Buildings in hot regions need materials that limit heat gain, because this directly affects comfort and cooling energy use. Concrete is the most common structural material, yet it readily absorbs heat and releases it slowly, which tends to raise indoor temperatures and increase reliance on air-conditioning. One approach is to add phase change materials (PCMs), which take in heat as they melt and give it back as they solidify, thereby damping temperature swings (Ling & Poon, 2013). The present work looks at how adding PCM to concrete influences both its temperature behaviour and its compressive strength. Different PCM dosages will be compared with ordinary concrete, with the wider goal of contributing to energy-saving, durable construction materials for hot climates.



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II. LITERATURE REVIEW

PCMs in Cement-Based Materials A PCM stores heat while changing from solid to liquid and releases it on returning to the solid state, so building elements containing PCM experience smaller temperature variations (Ling & Poon, 2013). Paraffin wax is a popular choice owing to its good heat-storage behaviour. Mixing it directly into cementitious materials, however, can cause the wax to leak when it melts and may weaken the hardened material. Recent reviews list leakage, loss of strength and uncertain long-term durability as the main obstacles to wider use in concrete (Al-Yasiri & Szabó, 2024; Rashid et al., 2023).

i) Use of Paraffin Wax and Expanded Perlite

Sun and Wang (2015) added paraffin/expanded perlite composites to cement mortar. The porous perlite held the wax by capillary action, with the composite carrying up to roughly 65% wax by mass. Both compressive and flexural strength fell as more composite was added, which shows that the dosage has to be controlled. To tackle leakage, Ramakrishnan et al. (2015) coated expanded perlite with a hydrophobic layer before loading it with paraffin. The coated composite retained wax better than the uncoated one in cement-based mixes, and concrete panels containing it showed improved thermal inertia and energy storage. The study underlines that a stable PCM composite should be prepared before it is mixed into concrete.

Improving PCM Stability Liu et al. (2018) wrapped paraffin/expanded perlite in a calcium silicate shell to create a form-stable PCM for mortar. The composite changed phase near 24.58 °C and had a latent heat of 88.57 J/g. Strength again declined with higher PCM content, although the shell reduced defects at the interface between composite and cement matrix. Encapsulation and surface treatment therefore affect both thermal and mechanical behaviour.

ii) Thermal Behaviour and Strength: How PCM concrete performs depends on the PCM type, its transition temperature, the amount used and how it is introduced. Porous PCM carriers can alter density, pore structure and bonding within the matrix, which in turn influences strength and thermal conductivity. Reconciling heat storage with mechanical performance is repeatedly identified as the core difficulty in this field (Al-Yasiri & Szabó, 2024; Rashid et al., 2023). Effect of PCM on Thermal Regulation and Compressive Strength

A review by Kahandawa Arachchi et al. (2025) examined the use of PCM in concrete, including thermal applications and fire performance. The authors highlighted the importance of selecting suitable PCM types and addressing issues associated with strength loss, leakage and behaviour at elevated temperatures. Their review also identified a need for further research into PCM systems that can provide thermal benefits without compromising the performance required for construction applications.



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Research Gap

The literature indicates that paraffin-based PCM supported by expanded perlite can improve the thermal energy storage capacity of cementitious materials. However, increasing PCM content may reduce compressive strength, and leakage remains a concern when the material is not adequately stabilised. Although several studies have investigated PCM-integrated mortar and cementitious panels, the results cannot automatically be applied to every concrete mix because aggregate grading, mix proportions, curing conditions and exposure temperatures differ.

For this reason, further experimental investigation is required to identify a suitable PCM replacement level for concrete exposed to hot climatic conditions. The present study focuses on incorporating paraffin-based PCM, supported by perlite, into concrete and comparing different replacement levels with conventional concrete, rather than assumed in advance.

III. METHODOLOGY OF PROPOSED SURVEY

Research Design

The present study adopts an experimental approach to investigate the thermal regulation and compressive strength of concrete incorporating phase change material (PCM) under hot climatic conditions. Paraffin wax is selected as the PCM, while expanded perlite is used as a porous supporting material to retain the paraffin and minimise leakage. The experimental programme involves preparing conventional concrete and PCM-integrated concrete specimens with different replacement percentages. Their thermal and mechanical properties will be evaluated and compared to identify a suitable PCM content.

Materials Selection

The materials proposed for the investigation include Ordinary Portland Cement (OPC) 53 grade, fine aggregate, coarse aggregate, paraffin wax, expanded perlite and water. Paraffin wax is used for its latent heat storage capacity, whereas expanded perlite acts as a carrier due to its porous structure. Cement, aggregates and water form the concrete matrix. The physical properties of the constituent materials will be determined or obtained from reliable material specifications before the preparation of the concrete mixes.

Preparation of PCM Composite

Expanded perlite will be prepared under suitable moisture conditions and dried where necessary. Paraffin wax will be heated to its melting range and introduced into the porous structure of the expanded perlite under controlled conditions. The resulting paraffin–perlite composite will be cooled and examined for visible leakage. The mass of paraffin absorbed and the proportion of perlite will be recorded to establish the composition of the PCM composite before incorporation into concrete.

Concrete Mix Proportioning

A control mix without PCM and modified mixes containing different PCM replacement levels will be prepared. The proposed replacement levels are 0%, 5%, 10% and 15%, designated as M0, M5, M10 and M15, respectively. The replacement basis will be clearly defined in terms of mass or volume and will specify whether the percentages refer to paraffin wax alone or to the complete paraffin–perlite composite.

The concrete mix proportions will be established using an appropriate mix-design procedure. The water content, mixing sequence, mixing duration and compaction procedure will be maintained consistently across the mixes wherever practicable. Fresh concrete workability will also be recorded to assess the influence of PCM incorporation on the fresh properties of the mixture.

Casting and Curing of Concrete Specimens

Concrete specimens will be cast in cube moulds measuring 150 mm × 150 mm × 150 mm. Each specimen will be labelled according to its mix designation to ensure accurate identification throughout the experimental programme. The specimens will be demoulded after approximately 24 hours, subject to adequate initial hardening, and cured under controlled conditions. Compressive strength testing will be conducted at specified curing ages, such as 7 and 28 days, in accordance with the applicable testing standard.



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Thermal Performance Evaluation

The thermal performance of conventional and PCM-integrated concrete will be evaluated under comparable heating conditions representative of the intended hot-climate application. Temperature sensors will be positioned consistently on the specimen surface and, where feasible, within the concrete to monitor temperature changes during heating and cooling. A data logger will be used to record temperature at predetermined intervals.

The recorded temperature data will be analysed to determine the maximum temperature, temperature rise, time required to reach peak temperature and temperature variation during the exposure period. Ambient temperature, exposure duration and other relevant environmental conditions will also be recorded to ensure a meaningful comparison between the control and modified mixes.

Compressive Strength Testing

The compressive strength of the concrete specimens will be determined using a compression testing machine in accordance with the applicable concrete testing standard, such as IS 516. Tests will be conducted at the specified curing ages, and multiple specimens will be tested for each mix to improve the reliability of the results.

IV. CONCLUSION AND FUTURE WORK

This research is about studying how phase change material (PCM) affects the temperature control and strength of concrete in hot weather. Paraffin wax is used as the PCM, and expanded perlite is used to hold the wax and reduce leakage. Different percentages of PCM will be added to concrete, and their performance will be compared with normal concrete.

PCM can absorb heat when the temperature increases and release the stored heat when the temperature decreases. This may help reduce temperature changes in concrete. However, adding PCM may also reduce the strength of concrete, so it is important to check both thermal performance and compressive strength.

The main purpose of this study is to find the most suitable percentage of PCM that provides better temperature regulation without affecting the required strength of concrete. This research may help develop better concrete for buildings in hot climatic areas. Further testing is needed to understand its durability and long-term performance.

EXPECTED OUTCOMES AND LIMITATIONS: On the basis of earlier studies, PCM is expected to lessen temperature fluctuation and delay the peak, while compressive strength is expected to drop as PCM content increases. These are expectations only and will be tested by the experiments. The study is confined to one PCM-carrier system, four dosage levels and short-term laboratory exposure. Durability, repeated-cycle leakage and full-scale building performance are outside its scope. **DECLARATION ON THE USE OF AI TOOLS** AI tools were used to assist with language editing, structuring and formatting of this manuscript. The authors have reviewed the content and take full responsibility for it.

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